METHOD FOR MEASURING GAP BETWEEN MASK AND SUBSTRATE OF DISPLAY PANEL

Background of the Invention

1. Field of the Invention

The present invention is related to a method for measuring a gap between a mask and a substrate of flat panel displays, such as plasma display panels and liquid crystal displays.

2. Description of the Related Art

Fabrication of flat panel displays includes photolithography for providing patterns on substrates of flat panel displays. The photolithographic process includes exposure, which is achieved by aligners.

Aligners for fabrication of flat panel displays often adopt a proximity exposure method. The proximity exposure method involves maintaining a small gap, 50 to 250 microns wide, between the substrate and the mask during exposure. This gap minimizes mask damage.

A conventional aligner for proximity exposure is disclosed in Japanese Unexamined Patent Application No. Jp-A 2001-12905. Fig. 1 shows a schematic of the conventional aligner, which is denoted by a numeral 150. The aligner

150 includes a substrate stage 106 having an upper surface 106S. A transparent substrate 104, such as a glass substrate, is secured by vacuum clamping on the upper surface 106. The upper surface 106S is square, having a side-length of L6.

The substrate stage 106 is drivingly connected to the stage drivers 143, which are respectively controlled by controllers 140. The posture control of the substrate stage 106, including the height control and leveling, is achieved by the controllers 140 and the stage drivers 143.

As shown in Fig. 2, the substrate 104 is square, having a side-length of L4. The main surface of the substrate 104 is covered with a photo resist 104a other than reflective square regions near the corners of the main surface of the substrate 104. That is, the substrate 104 is exposed at the square regions. The exposed square regions are referred to as gap measuring reflector regions 105, hereinafter. The gap measuring reflector regions 105 have a side-length of L5.

As shown in Fig. 1, the aligner 150 includes a frame-structured mask stage 3 onto which a square mask 101 having a side-length of

L1 is secured. The mask 101 has a main surface opposed to the substrate 104, on which a pattern to be transferred is formed. As shown in Fig. 3, transparent gap measuring marks 102 are disposed near the respective corners of the mask 101. The gap measuring windows 102 are square, having a side-length of L2.

As shown in Fig. 1, the aligner 150 further includes laser beam emitters 107 such as laser diodes, and laser beam detectors 108, such as photo diodes, both being disposed over the mask 101. The laser beam emitters 107 project laser beams 109 onto the gap measuring windows 102 at an angle of 45 degree to the mask 101. A part of each laser beam 109 is reflected by the mask 101 to generate a reflected beam 110, while the other part of the each laser beam 109 passes through the gap measuring windows 102 to generate a reflected beam 111. Each of the laser beam detectors 108 receives the reflected beam 110 from the mask 101, and the reflected beam 111 from the substrate 104.

Exposure by the aligner 150 begins with positioning the mask 101 and the substrate 104 so that the centers of the windows 102 and the reflector regions 105 are aligned.

Then, the gaps between the mask 101 and the

substrate 104 near the corners thereof are measured with the laser beam emitters 107 and the laser beam detectors 108. The laser b am emitters 107 respectively project the laser beams 109 onto the gap measuring windows 102 at an angle of incident of 45 degrees. The laser beam detectors 108 receive the reflected beams 110 from the mask 101 and the reflected beams 111 from the substrate 104, and generate spot position data representative of the positions of the spots where the laser beam detectors 108 receives the reflected beams 110 and 111. The spot position data may be representative of the distance between the spots of the reflected beams 110 and 111 provided on the laser beam detectors 108. The controllers 140 calculate the associated gaps between the mask 101 and the substrate 104 near the corners thereof on the basis of the spot position data received from the receivers 108.

The controllers 140 then operate the drivers 143 to control the posture of the substrate stage 106 so that the gaps becomes equal.

After the control of the posture of the substrate stage 106, the photo resist disposed on the substrate 104 is exposed through the pattern on the mask 101 with an ultraviolet light.

The conventional aligner thus described suffers from a problem that the pattern on the substrate is required to include reflective gap measuring marks. This undesirably reduces flexibility of the design of the pattern on the substrate.

An aligner for solving this problem is disclosed in Japanese Unexamined Patent Application No. Jp-A-Heisei 11-194501. The disclosed aligner includes The aligner is equipped with a substrate holder, a thickness measuring unit, a gap sensor and a controller. The substrate holder has an upper surface on which a substrate is secured. The thickness measuring unit measures the thickness of the substrate. The gap sensor determines the gap between the mask and the upper surface of the substrate holder. The controller calculates the gap between the mask and the substrate from the gap between the mask and the upper surface of the substrate holder and the thickness of the substrate, and regulates the gap between the mask and the substrate in response to the calculated gap. This eliminates the need for providing reflective gap measuring marks on the substrate.

Another aligning method is disclosed to achieve accurate alignment of the mask and the

substrate in Japanese Unexamined Patent Application No. Jp-A-Heisei 7-260424. The aligning method involves providing first alignment marks consisting of diffraction gratings on the mask at predetermined intervals, and providing second alignment marks of diffraction gratings on the substrate. A laser beam emitted from a He-Ne laser is projected onto the mask and the substrate, and diffracted by the first and second alignment marks respectively disposed on the mask and the substrate. The relative position of the mask and the substrate is determined on the basis of the diffracted beams from the first and second alignment marks. The use of the diffracted beams enables accurate determination of the relative position. The mask and the substrate are then aligned in response to the determined relative position. The accurate determination of the relative position allows the mask and the substrate to be accurately aligned.

Recently, sizes of substrates of flat display panels have been enlarged to improve production efficiency. Substrates having a length more than one meter, for example, are commercially available. Enlargement of the substrates allows a plurality of display device to be fabricated on a single substrate, and thus

decreases the number of required steps. For example, a large substrate on which a plurality of display device is fabricated reduces the number of exposure processes necessary for fabricating the same number of the display device. This effectively reduces fabrication cost of display devices.

Enlargement of the substrate, however, raises a problem of an undesirable deflection of the mask, because the enlargement of the substrate is inevitably accompanied by the enlargement of the mask to achieve exposure onto the enlarged substrate. The deflection of the mask prevents the gap between the mask and the substrate from being homogeneously regulated to a desired gap, and thus enlarges the difference in the dimension of the pattern transferred to the substrate. In a region where the gap is larger than the desired gap, for example, the width of lines transferred to the substrate are undesirably larger than the desired width, and vice versa. As a result, the width of lines undesirably varies widely on the substrate.

To remove or release undesirable deflection of the mask, the deflection of the mask is desirably measured or determined. A need exists to provide a technology for determining the

deflection of the mask.

Summary of the Invention

In summary, the present invention addresses determining and removing deflection of masks used for proximity exposure onto enlarged substrates. Determining and removing deflection of a mask provides a step for homogeneously regulating the gap between the mask and the substrate.

In an aspect of the present invention, a method is composed of:

providing a mask which includes:

an array of patterns, each of which corresponds to a display device,

a window disposed between two of the patterns,

placing a substrate to face the mask;

projecting an incident laser beam onto the substrate through the window of the mask; and

determining a gap between the mask and the substrate in a middle region of the substrate in response to first and second reflected beams, the first reflected beam being generated by the incident laser beam reflected by the mask, and the second reflected beam being generated by the incident laser beam being reflected by the substrate.

Determining the gap between the mask and the substrate in the middle region advantageously provides a step for removing or releasing undesirable deflection of the mask.

The patterns disposed may be arranged in a row or in rows and columns.

When the mask includes other windows disposed around the array of the patterns, the method preferably includes:

projecting other incident laser beams onto the substrate through the other windows;

determining gaps between the mask and the substrate near corners of the substrate in response to third and fourth laser beams, the third laser beams being generated by the other incident laser beams being reflected by the mask, and the fourth laser beams being generated by the other incident laser beams being reflected by the substrate, and

determining a deflection of the mask based on the determined gap in the middle region and the gaps near the corners.

When the substrate is covered with a photo resist, it is advantageous that a portion of a main surface of the substrate is exposed, and the second reflected laser beam is generated by the incident laser beam being reflected by the

exposed portion.

In an another aspect of the present invention, an proximity exposure method comprising:

providing a mask which includes:

an array of patterns, each of which respectively corresponds to a display device,

a window disposed between adjacent two of the patterns,

placing a substrate on a substrate stage opposed to the mask;

projecting an incident laser beam onto the substrate through the window of the mask; and

determining a gap between the mask and the substrate in a middle region of the substrate in response to first and second reflected beams, the first reflected beam being generated by the incident laser beam reflected by the mask, and the second reflected beam being generated by the incident laser beam being reflected by the substrate; and

removing a deflection of the mask in response to the determined gap in the middle region.

the removing preferably includes:

securing the mask and a glass plate to form a sealed space between the mask and the glass

plate; and

inflating or evacuating the sealed space in response to the determined deflection.

The determination of the gap in the middle region may be executed every time the substrate is exchanged or every time the mask is exchanged.

Brief Description of the Drawings

Fig. 1 is a schematic of the conventional aligner 150;

Fig. 2 shows a plan view of the substrate 104;

Fig. 3 shows a plan view of the mask 101;

Fig. 4 shows a plan view illustrating an alignment of the mask 101 and the substrate 104;

Fig. 5 shows a plan view of a mask used in an embodiment of the present invention;

Figs. 6 and 7 are schematics of an aligner used in the embodiment of the present invention;

Fig. 8 is a block diagram of the aligner;

Fig. 9 shows a deflection remover used in the embodiment;

Fig. 10 shows a plan view of a substrate with reflective regions;

Figs. 11 and 12 show a method of determining gaps using the reflective regions provided for the substrate;

Fig 13 shows a plan view of a substrate in an alternativ embodiment; and

Fig. 14 shows a plan view of a substrate in another alternative embodiment.

Description of the Preferred Embodiments

Preferred embodiments of the present invention are described below in detail with reference to the attached drawings.

In one embodiment, a glass mask 51 shown in Fig. 5 is used to achieve exposure. The glass mask 51 includes an array of the patterns 52 and 53, each of which corresponds to a complete display device (not to a portion of a display device). The patterns 52 and 53 are transferred to a substrate by a photolithography technique.

The glass mask 51 includes gap measuring windows 2 around the patterns 52, and 53. The gap measuring windows 2 are transparent regions to allow light to pass through. The gap measuring windows 2 are positioned in the corners of the mask 51.

A gap measuring window 2a is additionally disposed in a non-patterned region (or blank space) between the patterns 52 and 53.

Fig. 6 shows an aligner 50 used to achieve proximity exposure in this embodiment. The

aligner 50 includes a frame-structured mask stage 3, a substrate stage 6, laser beam emitters 7, and laser beam detectors 8. The substrate stage 6 has an upper surface 6S on which a substrate 4 covered with a photo resist 4a is secured by vacuum clamping. The mask stage 3 supports the mask 51 so that the main surface of the mask 51 is opposed to the main surface of the substrate 4.

The laser beam emitters 7 and the laser beam detectors 8 are used to determine gaps between the mask 51 and the substrate 4 near the corners thereof. The laser beam emitters 7 project laser beams 9 onto the gap measuring windows 2. A part of the each laser beam 9 is reflected by the mask 51, while the other part of the each laser beam 9 passes through the mask 51, and is reflected by the substrate 4. The each laser beam detector 8 receives the reflected laser beam 10 from the mask 51 and the reflected laser beam 11 from the substrate 4, and generates spot position data representative of the positions of the spots where the each laser beam detector 8 receives the reflected beams 10 and 11. The spot position data may be representative of the distance between the spots of the reflected beams 10 and 11. The gaps between the mask 51 and the substrate 4 near the corners thereof are

calculated on the basis of the spot position data developed by th laser beam detectors 8.

As shown in Fig. 7, the aligner 50 additionally includes a laser beam emitter 13, and a laser beam detector 14 to measure or determine a gap between the mask 51 and the substrate 4 in the middle region thereof. The laser beam emitter 13 projects a laser beam 15 onto the gap measuring window 2a. A part of the laser beam 15 is reflected by the mask 51, while the other part of the each laser beam 15 passes through the mask 51, and is reflected by the substrate 4. The laser beam detector 14 receives the reflected laser beam 16 from the mask 51 and the reflected laser beam 17 from the substrate 4, and generates spot position data representative of the positions of the spots where the laser beam detector 14 receives the reflected beams 16 and 17. The spot position data may be representative of the distance between the spots of the reflected beams 16 and 17. The gap between the mask 51 and the substrate 4 in the middle region thereof is calculated on the basis of the spot position data from the laser beam detector 14.

As shown in Fig. 8, the laser beam detectors 8 and 14 respectively provide the spot

position data for a controller 40 to determine the gaps between the mask 51 and the substrate 4. In response to the spot position data from the laser beam detectors 8, the controller 40 determines the gaps between the mask 51 and the substrate 4 near the corner thereof. Furthermore, the controller 40 determines the gap between the mask 51 and the substrate 4 in the middle region thereof in response to the spot position data from the laser beam detector 14. The controller 40 is responsive to the determined gaps (including both near the corners and in the middle region) for operating the stage driver 43 to control the posture of the substrate stage 6.

In addition, the controller 40 calculates the deflection of the mask 51 on the basis of the gaps near the corners and in the middle region. The controller 40 displays the calculated deflection of the mask 51 on the screen of the display 44.

The determination of the gaps between the mask 51 and the substrate 4 on the substrate stage 6, and the calculation of the deflection of the mask 51 may be periodically executed. For example, the determination of the gaps and the calculation of the deflection may be executed every other week or month. The periodic

determination of the gaps helps regulate the gaps between the mask 51 and the substrate to a desired value, when a predetermined numb r of substrates go through exposure by the aligner 50.

When the number of substrates going through exposure by the aligner 50 in a day is variable, the determination of the gaps between the mask and the substrate and the calculation of the deflection of the mask is preferably executed every time the substrate 4 is exchanged to be placed on the substrate stage 6, or every time the mask 51 is exchanged.

The calculation of the deflection of the mask 51 is preferably followed by removing the deflection from the mask 51. In order to removing the deflection from the mask 51, the aligner 50 preferably includes a deflection remover 60 as shown in Fig. 9.

The deflection remover 60 includes a transparent glass plate 61, and a mask holder 62. The glass plate 61 has the same size of the mask 51. The mask holder 62 fixes the mask 51 so that the mask 51 is opposed to the glass plate 61 to provide a sealed space 63 therebetween. The transparent glass plate 61 allows the laser beams 9 and 15 emitted from the laser beam emitters 7 and 13 to be projected onto the mask 51 and the

substrate 4 therethrough.

The mask holder 62 is provided with a gas inlet 62a and a gas outlet 62b. The gas inlet 62a is coupled to a tank 64 filled with high pressure air, and the gas outlet 62b is coupled to a vacuum pump 65. The tank 64 and the vacuum pump 65 is operated in response to the calculated deflection of the mask 51.

In the event that the mask 51 is convex toward the substrate 4, the vacuum pump 65 is operated to evacuate the sealed space 63. The evacuation of the sealed space 63 exerts a stress on the mask 51 toward the glass plate 61 to remove the deflection of the mask 51.

In the event that the mask 51 is convex toward the glass plate 61, on the other hand, the tank 65 is operated to inflate the sealed space 63. The inflation by the tank 65 exerts a stress on the mask 51 toward the substrate 4 to remove the deflection of the mask 51.

The pressure of the sealed space 63 is regulated by the tank 64 and the vacuum pump 65 in response to the gap between the mask 51 and the substrate 4 in the middle region thereof, that is, the deflection of the mask 51. This results in that the deflection of the mask 51 is appropriately removed.

As shown in Fig. 10, it is advantageous if square portions of the main surface of the substrate 4 are exposed, that is, not covered with the photo resist 4a to improve the reflection coefficient of the substrate 4. The exposed square portions in the corners of the substrate 4 are referred to as reflective regions 5, and the exposed square portion in the middle region of the substrate 4 is referred to as a reflective region 5a. The reflective regions 5 are positioned so that the reflective regions 5 face the gap measuring windows 2 disposed near the corners of the mask 51 when the substrate 4 is aligned to the mask 51. Correspondingly, the reflective regions 5a faces the gap measuring windows 2a in the middle region of the mask 51 when the substrate 4 is aligned to the mask 51. Application of the photo resist 4a by printing preferably facilitates the provision of the reflective regions 5 and 5a onto the substrate 4.

When the reflective regions 5 and 5a are provided on the substrate 4, as shown in Fig. 11, the laser beams 9 emitted by the laser beam emitters 7 are projected onto the reflective regions 5 through the gap measuring windows 2, and the laser beam 15 emitted by the laser beam emitter 13 is projected onto the reflective

r gions 5a through the gap measuring windows 2a as shown in Fig. 12. The reflective regions 5 and 5a increases the intensity of the reflected laser beams 11 and 17 from the substrate 4, and effectively improves the accuracy of the determination of the gaps between the mask 51 and the substrate 4.

In an alternative embodiment, with reference to Fig. 13, a mask 71 is used to achieve exposure in place of the mask 51. The mask 71 includes an array of the same patterns 72, 73, and 74 arranged in a row. Each of the patterns 72 to 74 corresponds to a complete display device (not to a portion of a display device). The patterns 72 to 74 are transferred to the substrate 4 by a photolithography technique.

The glass mask 71 includes gap measuring windows 2 near the corners thereof around the array of the patterns 72 to 74, which are transparent regions to allow the laser beams 7 to pass through.

A gap measuring windows 2b and 2c are additionally disposed on the mask 71 to allow laser beams to pass through. The gap measuring window 2b is disposed in a non-patterned region between the patterns 72 and 73, and the gap measuring window 2b is disposed in a non-

patterned region between the patterns 73 and 74. The gap measuring window 2b is positioned L/3 apart from the left edge of the mask 71, and the measuring window 2c is positioned 2L/3 apart from the left edge of the mask 71, where L is the length of the mask 71.

In order to determine gaps between the mask 71 and the substrate 4 near the corners thereof, laser beams are projected by the laser beam emitters 7 onto the substrate 4 through the gap measuring windows 2, and reflected laser beams are received by the laser beam detectors 8 from the mask 71 and the substrate 4. The gaps between the mask 71 and the substrate 4 near the corners thereof are determined on the basis of the positions of the spots of the reflected laser beams on the laser beam detectors 8.

Correspondingly, in order to determine gaps between the mask 71 and the substrate 4 in the middle region thereof, laser beams are projected onto the substrate 4 through the gap measuring windows 2b and 2c, and reflected laser beams are received by laser beam detectors from the mask 71 and the substrate 4. The gaps between the mask 71 and the substrate 4 in the middle regions thereof are determined on the basis of the positions of the spots of the reflected laser beams on the

laser beam detectors. The reflected laser beams associated with the gap measuring window 2b provide information on the gap at the position L/3 apart from the left edge of the mask 71. Correspondingly, the reflected laser beams associated with the gap measuring window 2c provide information on the gap at the position 2L/3 apart from the left edge of the mask 71.

The deflection of the mask 71 is calculated on the basis of the gaps between the mask 71 and the substrate 4 near the corners thereof and in those in the middle region thereof. In response to the calculated deflection of the mask 71, the deflection remover 60 is operated to remove the deflection of the mask 71.

In another alternative embodiment, as shown in Fig. 14, a mask 81 is used to achieve exposure in place of the mask 51.

The mask 81 includes an array of the same patterns 82 to 85 arranged in rows and columns. Each of the patterns 82 to 85 corresponds to a complete display device (not to a portion of a display device). The patterns 82 to 85 are transferred to the substrate 4 by a photolithography technique.

The mask 81 includes gap measuring windows 2 near the corn rs thereof around the array of

the patterns 82 to 85, which are transparent regions to allow the laser beams 7 to pass therethrough to determine the gaps between the mask 81 and the substrate 4 near the corners thereof.

A gap measuring windows 2d through 2h are additionally disposed on the mask 81 to allow laser beams to pass therethrough to determine the gaps between the mask 81 and the substrate 4 in the middle region thereof. The gap measuring window 2d is disposed in a non-patterned region between the patterns 82 and 83, and the gap measuring window 2e is disposed in a non-patterned region between the patterns 84 and 85. The gap measuring window 2f is disposed in a non-patterned region between the patterns 82 and 84, and the gap measuring window 2g is disposed in a non-pattern region between the patterns 83 and 85. The gap measuring window 2h is disposed at the center of the mask 81.

The determination of the gaps between the mask 81 and the substrate 4 is achieved by the aforementioned method. In order to determine gaps between the mask 81 and the substrate 4 near the corners thereof, laser beams are projected by the laser beam emitters 7 onto the substrate 4 through the gap measuring windows 2, and

reflected laser beams are received by the laser beam detectors 8 from the mask 81 and the substrate 4. The gaps between the mask 81 and the substrate 4 near the corners thereof are determined on the basis of the positions of the spots of the reflected laser beams on the laser beam detectors 8.

Correspondingly, in order to determine gaps between the mask 81 and the substrate 4 in the middle region thereof, laser beams are projected onto the substrate 4 through the gap measuring windows 2d to 2h, and reflected laser beams are received by laser beam detectors from the mask 71 and the substrate 4. The gaps between the mask 81 and the substrate 4 in the middle regions thereof are determined on the basis of the positions of the spots of the reflected laser beams on the laser beam detectors. The reflected laser beams associated with the gap measuring window 2d, 2e, and 2h provide information on the gap at the position L/2 apart from the left edge of the mask 81. The reflected laser beams associated with the gap measuring window 2f provide information on the gap at the position L/4 apart from the left edge of the mask 81. The reflected laser beams associated with the gap measuring window 2g provide information on the gap at the position

3L/4 apart from the left edge of the mask 81.

The deflection of the mask 81 is calculated on the basis of the determined gaps between the mask 81 and the substrate 4 near the corners thereof and in those in the middle region thereof. In response to the calculated deflection of the mask 81, the deflection remover 60 is operated to remove the deflection of the mask 81.

One skilled in the art would appreciate that laser beams are not required to be projected through all the gap measuring windows 2d to 2h. Preferable combinations of the gap measuring windows 2d to 2h used to determined the gaps in the middle region are as follows:

(1) the gap measuring window 2h,

(2) the gap measuring windows 2h, 2f, and 2g,

(3) the gap measuring windows 2d (or 2e), 2f, and 2g,

(4) the gap measuring windows 2f, and 2g,

(5) the gap measuring windows 2h, 2d (or 2e), 2f, and 2g, and

(6) the gap measuring windows 2h, 2d, 2e, 2f, and 2g.

Those who are skilled in the art would also appreciate that the number of the rows and columns in which patterns are arranged may be three or more.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been changed in the details of construction and the combination and arrangement of parts may be resorted to without departing from the scope of the invention as hereinafter claimed.